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Innovative Financing for Army Alternative Energy Projects

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An Investigation of Privately Financed Renewable Energy Projects for Army Installations

by

Henry M. Healey
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This report presents the results of an investigation to determine the feasibility of using private or third party financing to implement renewable energy systems at Army installations. Many renewable energy technologies were investigated, the present cost of energy from commercially available technologies was determined, and potential barriers to the use of third party financing for renewable energy projects were determined.

Two large-scale renewable energy technologies were identified that are likely to be attractive to private investors under third party financing arrangements because of their technical and economic success: concentrating photovoltaic systems and solar thermal electric systems. It is recommended that action be taken to implement these technologies on Army installations. Other technologies such as geothermal, ocean thermal energy conversion and tidal or wave energy conversion may be competitive with the cost of energy at selected installations. Existing energy costs and the cost of energy from renewable systems should be compared.

The results of this study indicate that while there are no real (legislative) barriers to impede implementation of energy projects using third party financing, there are perceived barriers that hamper the implementation of such projects. These impediments can be eliminated by providing an education program and incentive.

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FOREWORD

This research was performed for the U.S. Army Engineering and Housing Support Center under FAD No. 87-080566 dated September 1987, "Innovative Financing for Army Alternative Energy Projects." The Technical Monitor was Mr. Robert O'Brien, CEHSC-FU.

This study was performed by Henry Healey, P.E., President of Healey and Associates for the New Mexico Solar Energy Institute under contract DACA88-88-D-0029 to the U.S. Army Construction Engineering Research Laboratory (USACERL), Energy and Utility Systems Division (ES). Dr. G. Williamson is Chief of ES and Gerald Cler is the ES Principal Investigator. The USACERL technical editor was Gloria Wienke, Information Management Office.

COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

CONTENTS

AN INVESTIGATION OF PRIVATELY FINANCED RENEWABLE ENERGY PROJECTS FOR ARMY INSTALLATIONS

1 INTRODUCTION

Background

Federal law mandates that the Army, as well as other Federal agencies, investigate and consider using renewable energy systems.[1] The Secretary of Defense encourages solar energy systems as a source of energy for military construction projects when such systems are practical and economically feasible. Army experience with renewable energy systems has been less than ideal.[2] The majority of renewable energy systems at Army installations have been purchased and operated directly by the Army. Typical systems have been individually designed, one-of-a-kind, overly complex, and generally have not achieved the expected payback. Many of the systems have been plagued with operation and maintenance problems that often rendered them inoperative. While many such systems on both public and private installations have suffered similar problems, a greater number of renewable energy projects have been installed and operated successfully in the private sector under third party contracting (TPC) or shared savings arrangements, benefiting both the investor and the user. TPC of renewable energy systems at Army installations may offer the Army a practical method for meeting the goals and objectives of the Department of Defense (DOD) renewable energy initiative and for implementing solar projects that perform successfully.

Under TPC arrangements, the third party is responsible for the design, acquisition, installation, operation, and maintenance of the renewable energy system. These systems are typically a standard design installed under the direction of experienced construction project managers and operated efficiently and economically by experienced personnel. This arrangement provides both the investor and the user with a positive cash flow.

Until recently, TPC of energy projects were difficult to implement in the public sector because of legislative barriers. It was not until Title VIII, Section 801 of the National Energy Conservation Policy Act (NECPA) was passed by the 99th Congress giving Federal agency heads the authority to enter into shared savings contracts for up to 25 years, that private sector firms could seriously consider undertaking such projects. Section 2394, Title 10, U.S. Code permits an installation to enter into contracts for up to 30 years to purchase energy from production facilities. This was followed by 42 US Code 8287, which permitted Federal agencies to enter into shared energy savings contracts, and 10 US Code 2812 for the lease/purchase of facilities. These laws, however, while allowing multiyear contracts, created disincentives for TPC by stating in Section 802 that no Federal agency may obligate funds beyond any single year. A recent amendment (HR 4065) corrected this disincentive and provided for multiyear performance contracts based on shared savings "as long as budgets are not reduced during the contract period." Although this amendment corrected the problem to a degree, it leaves a significant issue (the impact of budget reductions) that must be addressed.

[1] 10 U.S. Code 2857.

[2] D. M. Joncich, "Active Solar Thermal Energy Research Program of the U.S. Army," *Proceedings of the American Solar Energy Society Annual Meeting* (1987).

Objectives

The primary objectives of this research were to identify renewable energy technologies applicable to Army installations that can be implemented today using shared savings or TPC and to develop recommendations or a plan to facilitate implementation of these technologies.

Secondary objectives of this work were to identify (1) impediments to TPC, (2) innovative financing options, and (3) potential participants likely to support TPC of renewable energy systems at Army installations.

Approach

This study was divided into two phases. The first phase identified candidate renewable energy technologies applicable to Army installations and determined the "cost of energy" from each. The second phase investigated TPC as a means of implementing renewable energy systems at Army installations. In the second phase, impediments to the implementation of TPC renewable energy projects, both perceived or real, were identified.

A task approach was used for this study. The overall objective was divided into the following tasks:

Task 1: Candidate renewable energy technologies applicable to Army installations, including low-temperature solar domestic water preheating; photovoltaic (PV) systems; wind energy conversion systems; and distributed receiver, solar thermal electric systems, were evaluated for commercial practicality. The following technically feasible and commercially available options were considered: (1) solar domestic water heating, (2) shallow solar ponds, (3) salt gradient solar ponds, (4) PV systems, (5) wind energy conversion systems, and (6) distributed receiver, solar thermal electric systems. The "cost of energy" from each technology was estimated to allow relative comparisons of economic feasibility among the technologies considered.

Task 2: Impediments to effective implementation of TPC, including the impact of the Federal Acquisition Regulations, Public Utility Regulatory Policy Act (PURPA) restrictions, current Internal Revenue Service (IRS) rulings, and the expiration of Federal tax credits were identified.

Task 3: Innovative financing options that might reduce renewable energy system costs to the private investor were evaluated. Options such as the use of State oil overcharge or bond funds to underwrite low-interest loans for privately financed renewable energy systems were considered.

Task 4: Potential participants likely to support innovative procurement strategies for third party Army renewable energy systems were investigated. Organizations considered included the power administrations, utility companies, Tennessee Valley Authority (TVA), non-Army Federal agencies, and State organizations.

Task 5: A plan to implement privately financed renewable energy systems at Army installations was developed.

Mode of Technology Transfer

Information in this report was presented to the Facilities Engineering Applications Program (FEAP) Executive Oversight Committee meeting in October 1989 and to the Corps of Engineers National Energy Team (CENET) in November 1989.

2 RENEWABLE ENERGY TECHNOLOGIES

Technology Overview

Although a wide variety of renewable energy systems can be purchased commercially, recent changes in the solar industry have made it much easier to identify the proven, commercially available technologies. It is in the Army's best interest to use only technologies proven by at least 2 years of satisfactory performance. The technologies considered in this work will be limited to such proven technologies as (1) solar domestic water heating, (2) shallow solar ponds, (3) salt gradient solar ponds, (4) PV systems, (5) wind energy conversion systems, and (6) distributed receiver, solar thermal electric systems. These technologies are commercially available and technically sound.

Solar Domestic Water Heating Systems

Solar energy is most efficiently used for the low temperature water heating required for domestic or building service use at Army installations. Examples include hot water for housing, barracks, dining facilities, laundries, and swimming pools. Solar energy has been used for more than 80 years in South Florida and California for these applications.[3]

A wide variety of solar energy systems are available to heat water. Small packaged systems designed to serve residential buildings are readily available. These systems include (1) integral collector storage units, which combine the collector and storage tank in a single unit, (2) thermosyphon systems with the tank located above the collectors, and (3) active solar systems using several different design strategies to prevent freezing.

Commercial and industrial buildings using moderate amounts of hot water require larger solar domestic water heating systems. These systems, normally sized to meet specific loads, are similar to the residential packaged active solar water heating systems, only larger. Typically, a multicollector array supplies a preheat tank with thermal energy and the entire system interconnects to the existing water heating system. Active solar water heating systems are typically mounted on the roof and use multicollector arrays in a closed loop, freeze protected system.

Shallow Solar Pond

The Shallow Solar Pond (SSP) is a large-scale solar water heating system designed to provide large quantities of hot water for high volume commercial and industrial use. The SSP is a modular, site-built, solar water heating system capable of providing in excess of 5,000* gallons of hot water per day. It is one of the lowest cost solar water heating systems for large scale applications.

Shallow solar pond systems use a modular approach in which SSP modules, built in a standardized size, are connected to supply the required load. An SSP module can be ground mounted or installed on a roof. It is typically 16 ft wide and up to 200 ft in length. The module contains one or two flat water bags similar to a water bed. The bags rest on a layer of insulation inside concrete or fiberglass curbs.

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[3] Ken Butti and John Perlin, *A Golden Thread* (Van Nostrand Reinhold, 1980).

* Metric conversion factors are on page 24.

The bag is protected against damage and heat loss by greenhouse type glazing that fits on the top of the curbs. A 200-ft pond filled to a 4-in. depth holds approximately 8,000 gallons of water.

The width of the SSP module (16 ft) has been selected to use standard, readily available components which results in an easy-to-fabricate, low cost design. SSPs are ideally suited for large scale, low temperature water heating applications. SSPs are most effective in the Southern latitudes, although they have been successfully installed as far north as Michigan. Lightweight SSP designs installed on roof tops are operational today in Jamaica and Puerto Rico, demonstrating that SSP systems do not necessarily require additional land areas.[4]

Salt Gradient Solar Ponds

A Salt Gradient Solar Pond (SGSP) is one of the simplest and least expensive technologies for the conversion and long-term storage of solar energy. Although SGSPs can provide energy for heating and cooling, process heating, and power generation, only the thermal applications for desalination and industrial process heating applications are commercially available. The chief advantage of SGSPs, over many of the other solar thermal systems lies in the ponds' ability to store thermal energy for several months. The chief disadvantage of the pond lies in site-specific and environmental aspects of the technology. SGSPs should be used carefully in environmentally sensitive areas where a leak could damage the environment.

A solar pond is a body of water that collects and stores solar energy. Although any large body of water can naturally collect about 75 percent of the sun's energy, much of this energy is lost by natural convective circulation. In SGSPs, convection is suppressed by increasing the salt concentration with depth from the pond surface, trapping substantial amounts of energy. A SGSP is filled with brine made from one of several salts. The concentration varies from a few percent at the surface to over 20 percent at the bottom. The pond has three distinct layers: the surface zone, containing a low salt concentration; the nonconvecting gradient zone, containing a concentration that increases with depth; and the bottom storage zone, containing a high concentration of salt. Although there is some mixing of these layers, they are quite stable because of the slow diffusion process of salt in water.

In the solar pond, solar radiation is absorbed by the liquid and the dark-colored pond bottom. The normal buoyancy of the warmer, deep water is suppressed by the nonconvecting gradient zone, because of the increased concentration of dissolved salt in the lower layer of the pond. The warmer water, which has a high salt content, is heavier than the cooler water in the upper zone. Heat is stored in the bottom of the pond. The surface and storage zones are convective. The gradient zone is nonconvective and separates the two convective zones, preventing full-depth natural convection. Heat trapped in the storage zone can be extracted by heat exchangers for both thermal and electric applications.

Although the primary use of SGSPs has been to provide thermal energy, a solar pond combined with an organic Rankine cycle power plant can be used to produce electricity. This plant uses an organic working fluid instead of water (steam). This is the system of choice for use with SGSPs because of the relatively small temperature difference available (180 °F). The principle of electric power generation with a solar pond (or any other solar source) is similar to conventional power plant steam generating systems. Hot brine pumped from the bottom of the pond is used to vaporize the organic working fluid. The

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[4] A. M. Lopez, "The Shallow Solar Pond for the Topics," Technical Paper presented at the VIII Inter-American Conference on Materials Technology, San Juan, Puerto Rico (1984).

vaporized organic fluid flows under high pressure to a turbine or expander that drives a generator similar to a conventional power generation plant. For this study, however, researchers considered only thermal uses of SGSPs.

Photovoltaic Systems

PV conversion of the sun's energy directly to electricity is a relatively new application of solar energy. The basic element of a PV system is the solar cell which converts sunlight into electricity. Although the most common type of solar cell is a thin disk of hyperpure silicon with a large surface area, other semiconductor materials are also used for solar cells. A typical cell produces approximately 0.5 volts (V). Its current output is proportional to the intensity of the sunlight and the area of the cell. PV cells are wired in series to increase the voltage and are wired in parallel to increase the system current output. Twenty to sixty or more cells are packaged together with a transparent cover (usually glass) and a watertight seal to form a module. These modules are wired together in a series/parallel combination to form an array that best meets the needs of an individual application.

Most of today's systems are used for remote power applications that require a small, reliable power source. Some typical applications include: radio and microwave repeater stations, warning and obstruction lights for buoys and offshore structures, and rural village power for lighting and pumping. However, the success of these small systems has recently been overshadowed by the megawatt utility-interactive central generating stations operating in California.[5] Regardless of the application, the basic operation is the same: sunlight is converted directly to electricity for immediate use, or is stored in batteries for later use. Because the intent of this study was to investigate the use of technologies suitable for use at Army installations where utility grid power is typically available, the focus was on the large, utility scale systems appropriate for private financing.

Modules or arrays are available in two basic types: flat-plate and concentrating. Flat-plate PV systems respond to both direct and diffuse sunlight; concentrators can use only direct sunlight. Flat-plate arrays can operate in either a fixed orientation or a sun-tracking mode. Tracking systems enable the array to capture more sunlight and tend to levelize the output during the collection hours. With a flat-plate tracking system, a smaller (less costly) PV array (compared to a stationary, fixed-tilt system) is required. The tracking structure usually costs more and requires more maintenance than stationary mounting, but the reduced size and cost of the array compensates for these increases. For most applications, flat-plate arrays are used in fixed orientation (notable exceptions are the central power stations that produce electricity in the Southwest). PV concentrators use only direct (beam) radiation and require sun tracking.

Five different types of PV systems are used in electric power generating applications: three based on flat-plate modules and two comprised of concentrating tracking arrays. Flat-plate systems can use a one- or two-axis tracking structure to track the sun as it moves across the sky during the day or can be fixed systems. Concentrating systems track the sun continuously and require one- or two-axis tracking structures.

The use of concentrators depends on the solar resource. In climatically clear areas of the Southwest, concentrators easily outperform flat-plate systems. In the Northeast, flat-plate systems outperform concentrators. In the Southeast, the performance difference between flat-plate systems and concentrators

[5] *Today's Photovoltaic Systems*, SAND 87-2585 (Sandia National Laboratories, 1987).

is more difficult to evaluate. For example, there is little cost difference between flat-plate and concentrating systems of equal energy output in Florida.

While the majority of concentrators provide only electric energy, one commercially available system provides both electric and thermal energy. The PV-thermal concentrating system has an inherent economic advantage over both the flat-plate and concentrating electric only systems for applications where there is a use for the thermal energy generated by the system.

The five PV systems use different array types because each type has some advantages. The first system uses a stationary, fixed-tilt, flat-plate array with no moving parts. It is the simplest and most reliable of all the PV options. The second system uses flat-plate modules on a one-axis tracking structure. The third system uses flat-plate arrays on a two-axis tracking structure that tracks the sun in both altitude and azimuth. The fourth uses concentrating PV modules and a two-axis tracking system that follows the sun precisely as it traverses from east to west. The fifth system uses a PV-thermal module that provides both thermal and electric energy. All of these systems are in operation today in the United States.[6]

Wind Energy Conversion Systems

Wind energy has traditionally served as a source of power for remote sites where no other source of power is available. Today, the use of the wind to provide both mechanical and electric power for small stand-alone applications is continuing. However, applying wind energy conversion systems (WECS) to dispersed grid-connected applications is overshadowing the stand-alone applications. Both systems have applications at Army installations worldwide.

The basic wind energy conversion device is the wind turbine (or windmachine or windmill). The wind turbine can provide mechanical power for applications such as pumping or for generating electricity. All wind machines have certain operating characteristics related to wind speed. Electrical wind generators are designed for high revolutions per minute (RPM) and low torque. Mechanical windmills operate at very low RPM with high torque. The cut-in speed, the speed at which the wind generator or windmill begins to produce power, varies depending on the equipment. Electrical generators normally begin to produce power when the wind is between 9 and 12 miles per hour (mph) depending on the design. As a rule of thumb, the larger the capacity of the electrical generator, the higher the cut-in speed. By contrast, mechanical systems will begin to produce power at speeds as low as 5 mph. This difference is primarily due to the rotor diameter and solidity ratio (the ratio of the blade surface area to the total frontal area). As the number of blade increases, so does the solidity.

Although the focus of this study is limited to using WECS to produce electricity at Army installations, these systems offer their greatest promise as a centralized supplier of electric power. Thousands of turbines installed in California windfarms are selling electricity to local utilities. In 1987, these windfarms delivered 1.7 billion kilowatt-hours (kWh) of electric energy.[7] The windfarm concept is being applied to a variety of electrical needs. If expansion is occurring at the end of distribution lines, windfarms can strengthen the system. If no power grid exists, a windfarm can be used to provide stand alone power. Windfarms offer flexibility and modularity and should prove quite valuable in suitable locations. Although there are several factors that govern the selection of a wind energy system, the wind

[6] H. M. Healey, M. Girgis, and B. Iyer, "Cost and Performance of Intermediate Sized Photovoltaic Systems in Florida," *ASHRAE Transactions*, Vol 94, Part 1 (1988).

[7] *Wind Energy Summary, Vol 1, Overview Fiscal Year 1988*, DOE/CH10093-41 (U.S. Department of Energy).

resource is perhaps the most significant factor. The output of a wind turbine varies with the third power (cube) of the wind speed. Wind energy systems require adequate resources to be cost effective.

Wind energy systems vary in size from watts to megawatts. The average rating of turbines installed in wind power stations has increased from 49 kW in 1981 to 101 kW in 1986 and the trend toward larger machines is expected to continue. Recent trends within the commercial sector have been on the production of machines with ratings between 100 and 330 kW and indications are that the size of the turbines will continue to increase. Most manufacturers expect to be producing machines rated at 200 to 600 kW by 1993. Production of larger machines can be expected to continue the decrease in cost (cost per kW) and the balance of system costs for installed systems.

Solar Thermal Electric Systems

Solar thermal electric systems use highly concentrated sunlight to produce thermal energy that can be converted to mechanical or electric power. There are three primary solar thermal technologies: (1) central receiver, (2) point-focus parabolic dishes, and (3) line-focus parabolic troughs. Modularity is one advantage of these distributed receiver systems. The basic building block is a row of reflectors actuated by a drive motor to track the sun. A control system operates the modules to track the sun and heat the fluid in the pipes to the required temperature. The energy level of these systems is supplemented up to 25 percent with fossil energy (natural gas). These hybrid systems have been shown to be quite effective.

Although systems using all three solar thermal technologies have been designed, built, and operated, only line-focus parabolic trough systems are commercially available today. Some work is continuing in the other technologies and should be monitored closely. Work on central receivers has essentially stopped.

The technology of the line-focus parabolic trough collectors is well established and has emerged as the leader in solar thermal electric generation. Today, 194 megawatts (MW) of electric power is being generated in Southern California using the line-focus parabolic trough technology; 80 MW was installed in 1988. The parabolic reflectors concentrate energy onto a receiver tube positioned along the focus of the trough. The collectors typically track the sun in one axis and operate between 200 and 600 °F.

Economics

As part of this research, the value or the effective "cost of energy" for each of the technologies was determined. This variable is based on climatic conditions, material and labor costs, and operating and maintenance costs over the operational lifetime of the installed system. The costs of the equipment, installation, and operation and maintenance were based on experience to date in the field. Climatic data from regions of the country where renewable projects are presently being implemented (the Southeast and the Southwest) was used to determine the output of the various systems. The system output and estimated installation and operation and maintenance costs were then used to determine the resultant cost of energy.

The resource data used to evaluate each of the technologies is detailed in the following paragraphs. For domestic water heating and flat-plate PV, an average daily insolation level (solar radiation received) of 1600 British thermal units (Btu)/sq ft was used. This level of insolation is readily available in many of the southern states. In evaluating the cost and performance of the solar thermal electric systems and PV systems using concentrating arrays, the resource available in the Southwest (New Mexico, Arizona, and Southern California) where annual sunlight availability is on the order of 2,250 Btu/sq ft/day was

used. In determining the cost of wind generated power, the resource available in California with average winds of 12 mph (where windfarms continue to be installed) was used.

Essentially, the resource data used to evaluate the various technologies was judged to be the minimum value required to encourage the implementation of renewable energy systems on Army installations in the immediate future. Potential sites having significantly more or less insolation, wind, or temperature extremes should be evaluated at the local conditions.

The cost of energy of the various systems is expressed as a levelized life cycle cost (i.e., \$/MBtu, \$/kWh, etc.) to enable direct comparison to present costs at Army installations. In determining the cost of energy in this study, a life cycle analysis was applied to the 20-year useful life of the various renewable energy systems to determine the levelized cost of energy.

The application of life cycle cost analysis requires the development of an economic scenario. This scenario refers to the economic conditions expected over the life of the project. Predictions must be made concerning costs and prices that will be encountered during the life of the project. Discount rates that reflect the time value of money as well as escalation rates for materials and labor must be determined. For this analysis, researchers used a 10 percent discount rate and a 5 percent escalation rate for operation and maintenance expenses and replacement materials was used. While these rates may differ from rates currently used by the Department of Defense, they are representative of those used by investors for third party financed projects.

Typical energy costs at Army installations are:

Electricity	\$0.04 to \$0.10/kWh
Natural gas	\$0.35 to \$0.50/therm
Liquid propane gas (LPG)	\$0.75 to \$1.25/gal
Oil	\$0.50 to \$0.75/gal

For comparison, the prices of conventional energy sources can be expressed in dollars per million British thermal units delivered to the load. Computing the thermal equivalent requires that the energy costs be adjusted to account for an efficiency of utilization, typically 100 percent for electricity, 70 percent for gaseous fuels, and 60 percent for oil. The resultant minimum costs are:

Electricity @ \$0.04/kWh	\$11.72/MBtu
Natural gas @ \$0.35/therm	\$ 5.00/MBtu
LPG @ \$0.75/gal	\$11.22/MBtu
Oil @ \$0.50/gal	\$ 6.01/MBtu

The 20-year levelized cost of energy from the renewable energy systems evaluated in this work and detailed in Appendix A was:

Solar Domestic Water Systems	\$9.40/MBtu
Shallow Solar Pond	\$5.72/MBtu
Salt Gradient Solar Ponds	\$3.75/MBtu
Photovoltaics	
Intermediate Sized Systems	
Flat-Plate	\$0.23/kWh
Concentrating	\$0.16/kWh

Large-Scale Systems	
Flat-Plate	$0.17/kWh
Concentrating	$0.06/kWh
Solar Thermal Electric System	$0.06/kWh
Wind Energy Conversion System	$0.08/kWh

The cost of energy shown above is the cost to the owner/operator as a result of the acquisition, construction, installation, and operation of the renewable energy system. Because of a number of factors, this is not the cost of energy from a renewable energy system installed under TPC arrangements.

In implementing renewable energy systems under a TPC agreement, the cost of energy to the user (the Army) would necessarily be 50 to 100 percent higher than the levelized cost of renewable energy determined in this work. A third party financed project must include consideration for transaction costs, return on the investment, and monitoring of the project's operation and savings. The transaction costs, which are fixed costs, limit the size of renewable energy projects. Projects must be large enough so that these costs to administer and set up the contracts and financing do not overburden the project savings. Based on discussions with a variety of TPC organizations, $500,000 is about the minimum size project recommended. In this study, only systems meeting this minimum size were evaluated.

Although TPC of renewable energy projects increases the cost of the systems to the user, it also increases the probability of successful implementation and operation. TPC places the responsibility of the project in the hands of the people with the specialized skills and knowledge necessary to implement successful projects and failure of the system results in no cost to the user (the Army).

3 THIRD PARTY FINANCING OF RENEWABLE ENERGY PROJECTS

Financing Options

Third party financing is a term that has been used to cover a variety of financing options used to implement energy conservation and renewable energy projects without a capital outlay by the user. In TPC, the capital required for projects or services is provided by outside investors, including manufacturers, contractors, financial institutions, or energy service companies. TPC is being used to finance energy supply projects and a wide variety of energy conservation measures and building retrofits for commercial, industrial, and institutional applications. Alternative financing can be an effective means of overcoming capital funding limitations that serve as barriers to implementing renewable energy projects of the type discussed in this report.

Four basic TPC options are available: (1) leasing, (2) joint venture, (3) shared savings, and (4) energy services contract. Each option has different advantages, risks, tax implications, and operating arrangements. While the Army can theoretically use any of the third party financing options, the shared savings or the energy services contract approaches appear to be the most likely arrangement for financing renewable energy projects on Army installations. In these options, the investor finances and owns the project or improvement (which may be on a military installation). The investor is responsible for the design acquisition, construction, and installation of the project as well as all associated operating and maintenance costs. Under leasing agreements, the project responsibility shifts to the user.

Joint ventures usually involve a using entity and one or more partners. Although suitable for large projects, joint ventures may be unnecessarily complex for some of the smaller renewable energy projects discussed in this report.

Since the early 1980's, TPC of renewable energy projects progressed in the private sector at an increasing rate. However, the loss of Federal and State tax incentives from the mid-1980's to the present combined with lower energy prices severely affected further implementation of private sector renewable energy projects using these financing arrangements. The initiation of new renewable energy projects using TPC has almost stopped. A number of firms and organizations that had been installing solar water heating systems on multifamily housing, condominiums, and other commercial and industrial buildings, have effectively gone out of business. One successful solar firm, which had been installing solar water heating systems in California using shared savings, has not installed a project since 1987. The PV industry has also slowed considerably. The large scale central station demonstration projects are no longer being built. Rather, the industry is focusing on small stand-alone projects for remote areas away from the utility grid. The explosive growth of windfarms in California has essentially stopped. Effectively, the solar energy industry that was on the verge of viable economic commercialization suffered a significant setback as a result of the removal of the tax credits serving to subsidize the technology.

Headquarters, U.S. Army Corps of Engineers (HQUSACE) is the organization responsible for establishing procedures and policies for implementing TPC legislation. HQUSACE developed a management plan to be used throughout the Army in developing third party energy projects. The plan provides the administrative structure and procedures necessary to implement projects at Army installations using TPC.[8]

[8] *Management Plan for Third Party Contracting/Alternative Financing For Energy or Fuel for Military Installations*, HND 1115-3-22 (U.S. Army Corps of Engineers, December 1985).

Impediments to Implementation

Impediments to the effective implementation of renewable energy systems using TPC for the Army can be characterized as economic, administrative, and legal (legislative).

Economic Issues

Economic impediments to private financing result from the current cost of renewable energy systems as discussed in the previous section of this report. The current cost of energy from most of the technologies examined is simply too high to be competitive with conventional sources and suppliers of energy at many Army installations. Additionally, the cost of energy from third party financed projects is typically 50 to 100 percent greater than the basic cost of energy developed in this study. Although the economics for the majority of the technologies examined is improving, the cost and value of such systems is not at the level required by individuals and organizations considering TPC of energy projects. For renewable energy systems to be successfully implemented in today's economic conditions under a third party arrangement, financial support or some other incentive will be required if such systems are to be installed at a significant number of Army installations.

The reduced and soon to expire tax credits have already affected the implementation of renewable energy projects. The economics of renewable energy systems, when evaluated only on the basis of avoided energy costs, are insufficient to justify implementation. Extension of the tax credit for renewable energy systems appears unlikely and in their present form cannot be recommended because of the potential for abuse of the credits.

While special tax credits for renewable energy systems may be desired by the industry, they are unlikely in view of the present budget deficit unless the credit can be tied to the environmental impact of the project. Concerns over global warming, acid rain, air pollution, adverse health effects, fuel spills, and other environmental problems associated with conventional power plants may provide an impetus to place an economic value on the environmental impact of future power generating systems. Such a value may be translated to an environmental tax credit that would be a benefit to renewable energy technologies without appearing to be direct financial assistance. Such a credit would logically be based on the capacity of the plant, resulting in a solar "harvest" credit. Such a credit, while serving the same purpose as the existing Federal tax credit, would most likely be more palatable to the policymakers.

Existing legislation, including Federal acquisition regulations, PURPA restrictions, and existing tax laws, while not prohibiting renewable energy applications, does little or nothing to encourage them. Recent actions in these legislative areas have in fact served to discourage the application of renewable energy systems.

The PURPA rules are undergoing evaluation. Although the effect of the Federal Energy Regulating Commission's (FERC) three new rulemaking decisions is not completely clear, several renewable industry representatives feel that FERC's "new" interpretation (of the PURPA) discards the original intent of the act, which was to enhance renewable energy applications through increased and protected access to the utility grid. Although the commission characterizes its approach as rejecting favored technologies, the contention is that bidding systems that examine only the readily accountable economic cost of new generating capacity are inherently biased toward coal-based and other conventional energy technologies that are more harmful to the environment than renewable resources. The new rule for bidding is likely to create a structure less amenable to wind and solar technologies than to coal and natural gas.

Administrative Issues

Currently, administrative issues appear to be the major obstacles to implementing energy projects with TPC. Although the major legislative difficulties are being or have been resolved, administrative issues remain a major obstacle. TPC does not have an effective contracting procedure that keeps both the government's and contractor's interests in balance. The administrative problems are the result of a general lack of communication about and experience with TPC coupled with the lack of incentive to undertake a procurement perceived as being more complex and of greater risk. Informal discussions have revealed that problems with existing procurement policies and processes and a general lack of understanding (and the resulting mistrust) of TPC on the part of both facilities and procurement personnel in the Federal government (Army) are also factors. These problems are effectively delaying and discouraging implementation of energy projects using TPC at government installations. They would, in the event a practical renewable energy project was identified at an Army installation, discourage and delay the project.

The existing procurement procedures applied to TPC of energy projects result in a significant cost to private companies. Companies interested in responding to a request for proposal (RFP) are required to complete a technical analysis at considerable cost before a contract is awarded. In the private sector, and in most State and local government transactions, TPC firms are not required to perform such an analysis until after an energy company has been selected and a contract is signed. A two-step solicitation could be used for Army projects. The first step would be a request for qualifications (RFQ) designed to provide complete information on the capability and experience of potential bidders. After review of the RFQs, a proposal would be requested from a much smaller group of companies or perhaps negotiations could begin with the top ranked firm. By following a two-step process, only those firms having a realistic chance of being selected will be required to bear the costs of the formal proposal and technical analysis.

Legislative Issues

The Federal Acquisition Regulations (FARs), as they are applied, are significantly hampering implementation of TPC of energy projects. It is not clear whether the difficulty arises from the actual language in the regulations or from their interpretation by contracting officers. The difficulties, as stated by the National Association of Energy Service Companies (NAESCO) at recent hearings before the House Subcommittee on Energy and Power, are as follows:[9]

> The termination for convenience procedure clause used in many solicitations allows the government broad leeway to terminate the contract with potentially great risk to the Energy Service Companies (ESCO). ESCOs put their working capital directly at risk and so have the potential of substantial capital losses. In a conventional services agreement, termination means that no additional services will be provided by the contractor and the client pays a termination amount for services rendered to date. In ESCO arrangements of this kind, the contractor has already purchased and installed equipment which in many cases is building specific and not project fundable. Hence, there may be real and material losses suffered by the ESCO should the government decide to terminate at will.
>
> There is widespread uncertainty whether provisions such as Buy-American, Davis Bacon, A-76, Cost and Pricing, among others are applicable to a performance contract. The applicability decisions, such as they have been, are of a piecemeal nature; once again, we know of no determination which is consistent in approach for all the branches and all the agencies. Lack of standardization of approach on key

[9] Nelson Hawk, "Comments of the National Association of Energy Service Companies," before the House Subcommittee on Energy and Power (1988).

contracting issues increases contractor cost and the likelihood that a contractor may decide not to bid on a project because the process is too cumbersome and unwieldy.

Another example of a provision which has caused some discussion is the use of different life cycle costing models. While life cycle costing is clearly the right mechanism to evaluate the economic merit of different options, there are a diversity of models which have been used by different agencies to meet this requirement. Thus, the ESCO is faced with the possibility that different procedures and sometimes different criteria will be used to evaluate the economics of their proposal.

FARs also prevent the Army and other Federal agencies from writing specifications that could identify specific renewable energy technologies that the agency might be interested in. Consideration should be given to allowing Federal agencies to specify the type of energy system to be used.

In their comments to the House Subcommittee on Energy and Power, NAESCO recommended that the FARs be modified to provide TPC firms with adequate damages in the case of termination for convenience. NAESCO also recommended that the FARs be reviewed on the basis of recent experiences in attempting to implement TPC contracts at Federal installations. The FARs, written before TPC projects were initiated, do not directly address the procurement issues that arise with such projects.

Sources of Financial Support

Sources of financial support for implementing third party financed renewable energy projects for Army projects were investigated as part of this work (see Appendix B). Direct and indirect financial support can take a variety of forms. Direct financial support could, in theory, be provided by State energy offices using oil overcharge funds. Low interest loans could be a practical means of support if they could be made available to TPC projects on Federal installations. Support from other organizations, such as the Federal power administrations, utility companies, and/or State organizations may also be useful in developing and monitoring TPC demonstration projects for Army installations.

In recent years, there has been a dramatic change in Federal spending related to renewable energy. During the 1980's, Federal energy programs have emphasized basic research and development of a nature not likely to be funded by private industry. The funding for commercialization and demonstration at the Federal level has all but disappeared. Today the majority of the funding for demonstration projects comes from State programs that have continued to be commercialization oriented. Although State programs were declining, they have been revitalized by oil overcharge funds in recent years.

State energy programs provide coordination, technical assistance, and financial support for State-initiated energy conservation (Public Law 94-163 and Public Law 94-385). State energy offices administer one or more of five Federal energy programs. These programs are: the State Energy Conservation Program (42 U.S. Code Section 6321); the Energy Extension Service (42 U.S. Code Section 7001); the Institutional Conservation Program, often referred to as the Schools and Hospitals Program (42 U.S. Code Section 6371); the Weatherization Assistance Program (42 U.S. Code Section 6861); and the Low-Income Home Energy Assistance Program (42 U.S. Code Section 8621). None of the Federal energy programs being administered by the States are research and development programs. However, several States have their own energy Research and Development (R&D) agencies and most States have one or more energy R&D programs within their State university system.

The Schools and Hospitals Program provides technical audits and funds 50 percent of the cost of energy conservation improvements for schools and nonprofit hospitals. The Weatherization Assistance

Program and Low-Income Home Energy Assistance Program provide low-income energy assistance. These three programs operate under a set of closely defined rules and formulas.

The State Energy Conservation Program (SECP) and Energy Extension Service (EES) offer greater latitude than the other three programs and, until recently, were small programs that encouraged the greater use of commercially available energy conservation techniques and renewable energy technologies. Typical activities included education, planning, and outreach plus small demonstration projects using commercially available technology. However, with the recent influx of oil overcharge funds, the opportunity to revitalize the energy conservation and renewable energy programs of the States has been provided.

The SECP and EES offer great latitude in the use of oil overcharge funds. These funds may be used to supplement the approved State Energy Conservation Plan. The current plan of most States contains a wide variety of energy conservation and renewable energy promotional efforts and, as a result, most projects that seek to increase public awareness of the energy and cost savings of commercially available conservation and renewable energy technologies are acceptable. Important prohibitions on the use of SECP funds are: (1) R&D programs are not allowed, and (2) equipment purchase is limited unless a demonstration is being conducted. No buildings or land may be purchased, and no highway or building construction may be funded (10 Code of Federal Regulations, Part 420). There are other prohibitions, but some actions precluded under the SECP are allowed under one of the other programs. The SECP of each State contains specific energy savings goals and projects funded seek to yield energy savings or recovery of renewable energy.

The EES is an energy outreach and education program targeted to specific categories of businesses such as farmers and hotels. Typical EES projects include demonstrations, seminars, training sessions, and production of public information materials. The prohibitions described in EES regulations are basically the same as those in the SECP.

Technologies promoted or demonstrated under SECP and EES should be commercially available. Research and development should be substantially completed and the technical validity proven. The technology, however, need not and should not be in widespread use (the intent of these programs is to get new technologies into the field). There should be mechanisms to inform the target audience of the benefits of the option being promoted and of the evaluation measures, such as energy savings data.

Policy guidance on the use of Exxon funds (oil overcharge) provided to State energy offices by the U.S. Department of Energy indicated that SECP and EES funds could be used to fund demonstration projects and to reduce the interest rate on an energy conservation loan. SECP funds can also be used to prepay a portion of the interest on an energy conservation loan provided by a private lender. Such demonstration projects and interest buy-downs could serve as direct financial support for renewable energy projects on Army installations.

Demonstrations under SECP and EES are often of interest since there are no limitations on equipment purchases. However, because of past General Accounting Office criticism of demonstrations, proposed projects are closely scrutinized, especially in the areas of informing the target audience, determining whether the target audience would implement the strategy, and planning for follow-on actions to increase the adoption of the technology.

Oil overcharge funds received by every State and territory have provided a tremendous opportunity for the energy conservation and renewable energy programs of the States. Each State, however, has

established its own priority and funding plan and use of the funds for specific Army demonstration projects would have to be pursued and approved on a State-by-State basis.

In addition to direct financial support, indirect support for work related to the development of renewable energy projects may be available from other sources, including the power administrations, utility companies, and the TVA. The five Federal power administrations may support some work related to the implementation of renewable energy projects in their service area.

Of the five power administrations (Western Area [WAPA], Bonneville [BPA], Alaska, Southwest, and Southeast), BPA has probably done the most to encourage the application of TPC and performance contracting. Their program, which involves approximately 38 buildings after about 4 years of effort, has not progressed very rapidly, however. The primary reasons are: (1) the incentives for TPC investors are minimal because of low power rates and (2) there is a question regarding the reliability of savings for these conventional energy conservation measures. It is possible that the BPA experience could be transferred to other power administrations where energy costs are higher. Conversations with WAPA indicated that they do have some limited funding that could support investigations of the use of renewable energy within their power marketing area.

Utility companies, their holding companies, and their subsidiaries are taking an active role in developing and implementing energy related projects. Such organizations may also provide support for Army renewable energy projects.

One of the most significant changes in renewable energy applications has been the joint ventures by utilities to become involved in manufacturing and marketing PV systems. Chronar has established relationships with several utilities (Alabama Power Company and Pacific Gas and Electric) to develop subsidiaries that would market PV electric power systems in the future. Glasstech has recently announced plans to build a 10-MW production facility as a joint venture with Toledo Edison Company. This would be the world's largest privately financed PV power plant. All of these activities could lead to utility interest in financing/owning decentralized power production plants. Potomac Edison Power Company, Washington DC, has formed American Energy Corporation which is currently part owner in three 30-MW solar generating installations; a fourth plant is under construction.

Virginia Power Company has entered into a joint venture with U.S. Windpower to study the potential construction of a 1.5-MW wind machine design. This venture, if successful, has the potential for expansion and marks the first large scale utility program in the continental United States. Additionally, Hawaiian Electric Renewable Systems, a subsidiary of Hawaiian Electric Company, operates the world's largest utility-owned windmill system with a capacity of 17.9 MW; the installation of 37 privately financed Mitsubishi 250-kW turbines has pushed Hawaii's installed capacity to nearly 30 MW.

TVA's Alternative Energy Trust fund was established in 1982 to provide TPC incentives for solar and biomass applications. At least one project has been financed using these funds. Funding is still available but is limited to the TVA region. In this instance, TVA provided Huntsville, AL owners with an interest subsidy to make an effective 4 percent loan and monitored the system that provided hot water for a 150-bed hospital in Hartselle, AL. The hospital was billed at 20 percent less than the normal cost to heat the same amount of water using a conventional system.

4 IMPLEMENTATION PLAN

The implementation plan requires two phases of evaluation. The first phase is to identify potential sites where renewable energy systems are likely to be implemented using TPC. This requires that site-specific information be gathered and evaluated against the cost of energy from the various renewable energy systems. Information on the present cost of energy and climatic conditions at Army installations worldwide should be gathered and evaluated. This data should then be used in conjunction with preliminary cost data developed in this study to identify technologies that should be evaluated in more detail for each site.

The second phase of evaluation requires estimating the cost of the candidate technology installed at a specific site and performing an economic analysis of the third party involvement in the project. While a variety of methods could be used for this evaluation, one readily available tool for analysis is the ENVEST Program, developed by the Alliance to Save Energy, to compare energy conservation projects.[10] This methodology can be used to compare the economic considerations involved in decisions to purchase energy or to establish performance contracting arrangements. As an example, the ENVEST program methodology requires input data such as: schedule of expenses (initial cost, maintenance, service contracts, etc.), savings or reductions in energy use (fuel type and quantity), and economic data (depreciations, tax credits, etc.). Project input files containing cost and performance information should be created for each technology. A series of "shared" data files, some of which would contain energy processes and demand charges for specific geographical locations, should also be developed. The ENVEST Program allows Army project managers to calculate measures of investment merit including payback, net present value, and internal rate of return; develop sensitivity analysis; and rank projects accordingly. Managers may also compare alternative financing options such as loans, leases, and shared savings arrangements. Although ENVEST cannot substitute for sound engineering analysis and cannot tell how to save energy, it can use data to prepare sophisticated analyses that can help managers make better-informed investment decisions. After completing the second, more detailed economic evaluation, the "best" Army sites for implementation of renewable energy technologies can be identified.

Because a major impediment to implementing renewable energy projects using TPC lies in the lack of communication and experience with the process on the part of both facility and procurement personnel, a training program addressing these areas should be established. In conjunction with the training program, it is appropriate to explore methods of providing incentives for Army personnel to undertake third party financed projects.

[10] ENVEST: Energy Efficiency Investment Analysis Software (Alliance to Save Energy, 1986).

5 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Implementing renewable energy systems using TPC is a strategy that should be pursued by the Army. Of the six technologies evaluated in this research, two stand out as likely candidates for implementation using TPC: (1) large scale concentrating PV systems and (2) solar thermal electric systems. The levelized cost of energy from both technologies is approximately $0.06/kWh, which is attractive for daytime use at many Army installations. Both technologies produce electricity, which is much easier to transport and measure accurately than thermal energy. This can be advantageous when attempting to site a TPC project. The energy produced can be sold to the installation through an electric meter.

Although the TPC approach will increase the cost of energy from renewable energy projects, this is the most reliable approach to successful implementation of such projects. The infrastructure for implementing these technologies under TPC arrangements exists and is being used in the private sector. The minimum project size for TPC projects is about $500,000.

Administrative issues can be a major obstacle to using TPC to implement energy projects. Because facilities and procurement personnel do not understand TPC, the process can be delayed. During the planning stages of a TPC project, many of the administrative issues can be handled by U.S. Army Engineer Division, Huntsville. This removes some of the contracting burden from the installation. The installation will be required to monitor the contract once it is in place. In contrast to private, State, and local policies, the Federal procurement policies and processes require companies to complete a costly technical analysis before being awarded a contract. The economic impediment to effective implementation of renewable energy systems using TPC results from reduced and soon to expire tax credits. Although existing tax laws and regulations do not prohibit renewable energy applications, they do not encourage their implementation. The legislative impediment to TPC results from either the actual language of the FARs or the interpretation of the language by contracting officers.

Of the four TPC options evaluated in this research, the shared savings and the energy services contract approaches appear to be the most likely arrangements. In these arrangements, the investor finances and owns the project and is responsible for design, construction, installation, and operating and maintenance costs.

A variety of organizations and programs were identified during this research as potential sources of financial support. Federal power administrations, utility companies, and State organizations may also provide support through such programs as the Schools and Hospitals Program, the Weatherization Assistance Program, or the State Energy Conservation Program as long as the project meets specific rules and formulas. However, a recent influx of oil overcharge funds provides the greatest opportunity to revitalize the energy conservation and renewable energy programs for the States.

Recommendations

It is recommended that a tax credit that can be tied to the environmental impact of a project be developed. This credit would benefit renewable energy technologies without appearing to be direct financial assistance.

A two-step solicitation process should be used for Army projects. The first step, a request for qualifications would provide information on the capability and experience of potential bidders. After review, a proposal and the accompanying technical analysis would be requested from the most eligible companies.

Federal Acquisition Regulations should be reviewed on the basis of recent experiences in implementing TPC contracts and revised to allow Federal agencies to specify the type of energy system to be used.

The implementation plan described in Chapter 4 should be followed.

METRIC CONVERSION TABLE

1 ft	=	0.305 m
1 gal	=	3.78 L
°C	=	0.55(°F-32)
1 mph	=	1.6 kph
1 Btu	=	1.055kJ
1 kWh	=	3600kJ
1 in.	=	2.54 cm
1 sq ft	=	0.0929 sq m

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42 U.S. Code, Section 6321, The State Energy Conservation Program.

42 U.S. Code, Section 6371, The Institutional Conservation Program (often referred to as the Schools and Hospitals Program).

42 U.S. Code, Section 6861, The Weatherization Assistance Program.

42 U.S. Code, Section 7001, The Energy Extension Service.

42 U.S. Code, Section 8287, Authority to Enter into Contracts.

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APPENDIX A:

COST OF ENERGY INFORMATION

Introduction

The cost of energy from each of the renewable energy systems presented in this report is calculated by dividing the life cycle cost of the system by the energy collected over the 20-year life of the system.

$$\text{Cost of Energy (CE)} = \frac{\text{Life Cycle Cost (LCC)}}{\text{Energy Quantity}} \qquad \text{[Eq A1]}$$

Solar Domestic Water Heating

The cost of energy from active solar water heating systems is a function of the installed costs of the system, the cost of operation and maintenance of the system over its expected life, and site specific factors including solar insolation, water supply temperature, and ambient temperatures.

The energy produced by a specific solar system at a specific site can be determined quite easily by Solar Energy Feasibility program (SOLFEAS)*, First Chart (FCHART),** or other computer simulation programs. For the purposes of this work, a standard Southeastern day with a daily insolation of 1600 Btu/sq ft was used to evaluate the system energy output.

Commercial active solar water heating systems are currently being installed at average costs between $40 and $60/sq ft. Costs for small systems, or those with minimal energy requirements (less than 500 gal/day), tend to be higher and could exceed $60/sq ft. Larger systems, more than 2000 sq ft, installed on buildings that can easily accommodate the system's space and structural requirements without modification, could approach installed costs of $40/sq ft. Many commercial active solar water heating systems have been installed in the southern United States for less than $50/sq ft. For this study, active solar water heating systems can be expected to cost $50/sq ft. The cost breakdown of conventional active solar water heating systems is readily available from existing installations and reports.

The cost of the energy from a solar water heating system can be determined by dividing the cost of installing, operating, and maintaining the system by the energy delivered to the load over its expected life. The life of solar water heating systems for the purpose of this analysis has been assumed to be 20 years.

Active solar water heating systems in the southeast typically collect 250,000 to 350,000 Btu/sq ft annually. The "first" cost of such systems averages $50/sq ft. Operation and maintenance is estimated to be 1 percent annually over the 20-year life. As part of the life cycle cost analysis, the annual operation and maintenance (O&M) cost is escalated at 5 percent, discounted at 10 percent, and brought to a present value. The effect of this present value computation results in adding 12.72 times the annual O&M cost (or $6.36) to the first cost, resulting in an effective cost of $56.36/sq ft for the system.

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*SOLFEAS is the Army's active solar energy feasibility program.

**FCHART is a program similar to SOLFEAS. It was developed at the University of Wisconsin.

The cost of energy from solar water heating systems based on the cost and performance outlined above is calculated as follows:

$$CE = \frac{\$56.36}{300{,}000 \text{ Btu/sq ft-yr} \times 20 \text{ yr}}$$

$$CE = \$9.40/\text{MBtu}$$

Shallow Solar Pond

Installed costs of SSP systems vary significantly with the size and configuration of the pond, the experience of the contractors, and the prevailing labor rate. Typical costs of SSPs, installed in the southeastern United States, have ranged from \$11 to \$27/sq ft.

Large pond installations using the standard length pond (200 ft) can be installed for \$12.00/sq ft. Smaller installations, however, with several small (50 ft) ponds will approach a cost of \$19/sq ft. For this analysis, shallow solar ponds were assumed to cost \$15.00/sq ft. A detailed cost estimate of a 4800-sq ft pond system has been prepared as part of this work. The cost of the system is estimated to be \$17.00/sq ft. The pond is composed of three 100-ft long pond modules.

A summary of the cost estimate of the system is as follows:

Sitework	\$ 4,470
Concrete	8,350
Insulation and Moisture Barriers	10,950
Pond Components	20,520
Controls	6,000
Mechanical	10,060
Electrical	2,700
Subtotal	\$63,050
General Requirements	9,800
Subtotal	\$72,850
Project Management (10%)	7,300
TOTAL	\$80,150

Shallow solar ponds in the southeast typically collect 200,000 to 300,000 Btu/sq ft of surface area per year. The first cost of the small SSP is \$17.00/sq ft, as shown previously. Annual operation and maintenance costs of SSPs should be about 1 percent. However, periodic component replacement will be required to achieve a 20-year life. After 10 years, the bags, glazing, and pumps should be replaced (at a cost of about 35 percent of the original cost). O&M costs of approximately \$2.16/sq ft and replacement costs of \$3.73 are added to the first cost, resulting in an effective cost of \$22.89/sq ft.

The cost of energy from a typical small size SSP is calculated as follows:

$$CE = \frac{\$22.89/\text{sq ft}}{200{,}000 \text{ Btu/sq ft-yr} \times 20 \text{ yr}}$$

$$CE = \$5.72/\text{MBtu}$$

Salt Gradient Solar Pond

Construction and installation costs of existing SGSPs is between $5.00 and $7.50/sq ft. The cost of the pond developed for this evaluation is based on 1983 construction costs of the 52,000 sq ft pond constructed by the TVA in Chattanooga, TN. This is the largest solar pond in the United States. It was installed for about $7.00/sq ft, and is a thermal system. The price breakdown (in dollars per square foot) is shown below.

1. Excavation and diking	$1.40
2. Salt at $30/ton	$1.60
3. Pond liners (2)	$2.30
4. Miscellaneous	$1.40
5. Heat Extraction System	$0.30

SGSPs can be expected to deliver approximately 20 percent of the incident solar energy. Using the 1,600 Btu/sq ft-day resource available in the Southeast, (a salt gradient pond can provide approximately 320 Btu/sq ft-day of thermal energy, or 117,000 Btu/sq ft-yr.

O&M cost estimates of the SGSP system are required for the life-cycle cost comparisons. Records of the O&M costs of solar ponds and with solar thermal collection subsystems were reviewed to estimate the O&M costs of a standard system. O&M costs reflect the cost of salt makeup chemicals to ensure clarity and prevent algae growth, debris removal, and inspection/repairs of liners. Advances in liner materials and leak detection methods should keep O&M costs just below 1 percent per year. O&M costs for the heat extraction system would add another 1 percent per year. Using the 52,000-sq ft pond as an example to determine the cost of energy, the total O&M costs for the entire SGSP system are estimated to be 2 percent or $0.14/sq ft/yr.

The cost of energy from the SGSP is determined using the life cycle cost analysis described previously. O&M expenses add $1.78/sq ft (12.72 x $0.14) to the installed cost of the ponds, resulting in an effective cost of $8.78/sq ft. As the SGSP is expected to deliver 117,000 Btu/sq ft-yr, the levelized (20-yr) cost of energy for the SGSP was determined to be $3.75/Btu.

$$CE = \frac{\$8.78/\text{sq ft}}{117{,}000 \text{ Btu/sq ft-yr} \times 20 \text{ yr}}$$

$$CE = \$3.75/\text{MBtu}$$

Photovoltaic Systems

The cost of the energy delivered by PV systems is primarily a function of the cost of the specific system type and size. PV systems are generally classified by array size as small, intermediate, or large systems. Array sizes less than 10,000 peak watts (10 kWp) are classified as small, arrays between 10 kWp and 1 MWp are intermediate, and arrays larger than 1 MWp are large systems. In this report, only the costs of energy from intermediate and large systems, the size likely to be implemented under TPC arrangements, were evaluated.

Flat-Plate Systems

The installed costs of the intermediate PV systems (Table A1) were estimated from the cost history of similar systems and recent bids from component and system suppliers. The costs are based on a cost-per-peak-watt factor ($/Wp) that refers to the power rating of the array under "peak" sun conditions.

The total installed cost reflects component prices for PV modules, the power conditioning unit (PCU), the balance of system (BOS), and design and construction project management (CPM) fees.

The cost of flat-plate tracking systems as reflected by the BOS cost is very sensitive to size. The cost shown here is valid for systems capable of delivering 500,000 to 1,500,000 kWh/yr (the minimum size likely to be implemented with TPC). The cost differential between the systems decreases with increasing system size. As the size of the system increases, the BOS costs will approach stationary system costs since economy of scale will reduce tracking hardware costs. A recent study indicates that for systems delivering 12,000,000 kWh/yr, the BOS cost of a tracking system per annual kWh delivered will be about equal to the BOS cost of a fixed system.

Table A1

Cost Breakdown of Intermediate Size Flat Plate Photovoltaic Systems

Elements	Fixed-tilt system	One-axis tracking	Two-axis tracking
PV modules	5.50*	5.50	5.50
PCU	0.60	0.60	0.60
BOS	0.50	1.50	2.50
Design and CPM	0.40	0.40	0.40
Total	7.00	8.00	9.00

*In dollars per peak watts.

For comparison, the costs of flat-plate systems in the Southeast (Florida) designed to deliver 700,000 kWh annually were evaluated. The array size for the various technologies varied from 441 kWp for the fixed flat-plate to 348 kWp for the two-axis tracking array.

A fixed tilt, flat-plate system rated at 441,000 Wp can be installed for about \$7.00/Wp. Most of the cost (\$5.50/Wp) is for the PV modules or panels. The \$5.50/Wp price is the average of past quotes for 350 to 450 kW of modules from several PV manufacturers. The remainder is for the PCU and BOS costs.

The one-axis tracking, flat plate system can be installed for about \$8.00/Wp. The cost of a 375 kWp system is \$3,000,000. The 348 kWp two-axis tracking system installed for \$9.00/Wp will cost \$3,132,000.

The O&M cost for the various systems is also an important consideration in determining the cost of energy, but it is extremely difficult to estimate accurately. The O&M costs of the stationary system would be the lowest of the three alternatives; about 0.3 percent or \$10,000/yr. This includes periodic inspection and repair or replacement of damaged or inoperative components. The O&M costs for the tracking systems are estimated to be 50 percent more than the fixed tilt system, or \$15,000/yr. The O&M costs for this intermediate sized system is based on recent studies by the Electric Power and Research Institute (EPRI). These costs should be quite realistic for the 700,000 annual kilowatt hour (AkWh) systems evaluated for this study.

The life cycle costs for the PV systems compared in this study would reflect both the initial cost and the O&M cost over the life of the project. The fixed-tilt system would cost \$3,087,000 initially and require \$10,000 each year for O&M. No replacement costs, other than those expected as part of the annual O&M, would be required over a 20-year lifetime. The annual O&M costs include a number of replacement modules. The present value of the \$10,000 annual expenditure for O&M, when considered on a life-cycle basis with a 5 percent escalation and 10 percent discount rate, is \$127,200. The total life-cycle cost of the fixed-tilt PV system is \$3,214,200 (3,087,000 + 127,200). The system cost can be expressed in a variety of ways; perhaps the most useful is on the basis of delivered energy. The resultant system cost on the basis of annual kilowatt hours delivered (AkWh) is \$4.59 for the stationary fixed-tilt system.

The one-axis tracking system, costing \$3,000,000 initially with annual O&M of \$15,000, will cost \$3,190,800 over a 20-year lifetime, resulting in an effective cost of \$4.56 per AkWh. The two-axis tracking system, with \$15,000 annual O&M expenses, will cost \$3,322,800 over the 20-year lifetime. The annual cost per delivered kWh for the two-axis tracking system is \$4.75.

The costs for the three different types of flat plate PV systems evaluated in this study delivering approximately the same amount of energy on an annual basis were within 5 percent of each other as shown in Table A2. The performance prediction on which these costs are based is accurate within 5 to 10 percent. The results of this comparative evaluation indicate that at current prices of intermediate size (10 kWp to 1 MWp) PV systems, there may be no significant economic difference between a tracking and a stationary system in the Southeast. Thus, selecting one system over the other would most likely be a function of other factors such as land area requirements and associated cost reliability or O&M concerns, or the delivered energy profile.

The cost of large scale flat-plate PV systems, while providing some economy of scale, will not provide significant decreases in costs. It is expected that the installed cost and resultant energy cost of large scale flat-plate systems will be a maximum of 25 percent less than the cost of the intermediate size systems. On this basis, the cost of large sized systems is as shown in Table A3.

Table A2

Cost Summary for an Intermediate Size Flat-Plate PV System in the Southeast

System	$/Wp	Total cost ($)	$/AkWh	Levelized cost, $/kWh
Stationary	7.00	3,214,200	4.59	.23
One-axis	8.00	3,190,800	4.56	.23
Two-axis	9.00	3,322,800	4.75	.24

Table A3

Cost Summary for a Large Size Flat-Plate PV System in the Southeast

System	$/Wp	$/AkWh	Levelized cost, $/kWh
Stationary	5.25	3.44	.17
One-axis	6.00	3.42	.17
Two-axis	6.75	3.56	.18

Concentrating PV Systems

The costs of the concentrating PV systems are somewhat more variable than flat-plate systems and are significantly affected by size and the existing production volume of the manufacturer. Presently, there are two manufacturers of concentrating PV systems: Entech, Inc. of Dallas, TX and Intersol Corporation of Denver, CO. Entech manufactures linear and point focusing fresnel lens concentrating systems that generate only PV electric power or both PV and thermal (PV-T) energy. Intersol's point focusing fresnel lens concentration systems provide electric power only. Both manufacturers provided information on the costs of a system sized to deliver between 500,000 and 1,500,000 kWh/yr, the minimum size likely to be implemented by TPC.

For electric production, the linear fresnel array, based on the cost of the 300-kW project in Austin, TX, is estimated to be $7.00 per delivered watt of alternating current (W_{ac}). The costs of these systems, taken from recent bids, vary with size from $7.00/$W_{ac}$ for a 300-kW system to $3.00/$W_{ac}$ for an 80-MW system. The 20-year levelized cost is $0.23 to $0.064/kWh. The point focusing systems prices also vary

significantly with production quantity because of the present market (or lack thereof) and range from $7.00/W installed for plants of 1 MW and $4.50/W for plants of 20 MW or more.

For this study, the cost of the point focusing concentrating system, sized to deliver 700,000 kWh/yr, was estimated to be $8.50/W, based on past quotes. However, the cost of a linear fresnel PV-T system to provide both thermal and electric energy would cost $8.00/W due to the additional cost of $1/W incurred for the thermal option. The additional cost is more than offset by the thermal energy collected. The useful thermal energy collected annually can be expected to approach 35 million Btu/kW.

The costs of concentrating systems capable of producing 700,000 kWh/yr were also determined using the costs and analysis procedure discussed previously. The basic costs of the 700,000 kWh/yr system are $8.50/W for the point focusing concentrating system, $7.00/W for the linear fresnel system and $8.00/W for the linear fresnel PV-T system. Annual O&M costs for concentrating systems should typically run 0.25 percent per year adding 3.18 percent to the life-cycle cost of the various systems.

The concentrating systems were evaluated in two locations for comparison: the Southwest, as installed today, and the Southeast. The cost and performance of the concentrating systems are shown in Table A4.

Table A4

Cost Summary for Intermediate Size Concentrating PV Systems (700,000 AkWh)

Southwest	Size kW	Total cost ($)	$/AkWh	Levelized $/kWh
Point focusing	253	2,218,886	3.17	0.1585
Linear PV	290	2,094,554	2.99	0.1496
Linear PV-T	290	2,393,776	3.42	0.1710
(PV-T system also provides 9895 MBtu/yr)				

Southeast	Size kW	Total cost ($)	$AkWh	Levelized $/kWh
Point focusing	414	3,630,904	5.19	0.2594
Linear PV	475	3,430,735	4.90	0.2451
Linear PV-T	475	3,920,840	5.60	0.280
(PV-T system also provides 9975 MBtu/yr)				

The cost of energy from the various PV systems can be judged by comparing either the cost per annual kilowatt hour or the levelized cost ($/kWh). However, in the case of the PV-T system, the cost should be divided between the electric and thermal energy produced. If you were to assign some percentage of the total cost to each form of energy, the effective cost of energy would be reduced accordingly.

The value of the cost of energy of the PV-T system can be proportioned between the electric and thermal energy produced in a number of ways. If you divide the cost of the systems equally, the cost of energy from the system would be as shown in Table A5.

As discussed previously, the cost of energy from concentrating PV systems will show dramatic changes with the size of the installation and the production rate at the manufacturing facilities. The manufacturers of commercially available concentrating systems have quoted prices as low as $3.00 per W_{ac} for large systems. The quoted prices were used in conjunction with estimated O&M costs to determine levelized costs of energy from such large scale systems. The system prices would result in a levelized cost of energy of $.064/kWh, which is significantly less than the cost of energy from comparable flat-plate PV systems.

Solar Thermal Electric

The economics of solar thermal electric (STE) systems are based on information from Luz International, the sole supplier of STE systems that meet the Army's requirements for commercial availability. According to Luz, the minimum plant size likely to be implemented with TPC is 30 MW although recent plants are projected to be 80 MW. A 30-MW plant located in a desert climate with insolation comparable to the Daggett, CA site will deliver approximately 90,000 MWh/yr of electric energy.[11] The cost of such a plant is estimated at $100,000,000, resulting in a cost of $1.11/kWh/yr and a levelized cost of $.055/kWh. It must be pointed out, however, that the Luz system requires natural gas to supply up to 25 percent of the thermal input which effectively ties the resultant cost of energy to the price of natural gas. A spokesman from Luz indicated that the investors would be interested in selling electricity from the plant at a rate of $0.10/kWh.

Table A5

20-Year Levelized Cost Summary for a 700,000-AkWh PV-T Concentrating System

Location	Size kW	$/kWh	$/MBtu
Southwest	290	0.085	6.048
Southeast	475	0.140	9.827

[11] D. Kearney and H. Price, "Performance of the SEGS Plants," *Proceedings of the Tenth Annual ASME Solar Energy Conference* (April 1988).

Wind Energy Conversion Systems

The cost of energy from wind energy systems is, as in the case of other renewable energy technologies, site dependent. The wind resource, however, is much more site specific and the process of siting a wind machine is extremely important.

The energy production, expressed in annual kilowatt hours, will vary from machine to machine and site to site. Since the power produced by a machine varies with the third power (cube) of the wind speed, the actual distribution or variation of the wind speed around the "average speed" often used to estimate the performance and economics is required. Once a wind resource at a site is characterized and month-to-month frequency and distribution profiles of wind velocities have been obtained, a fairly reliable estimate of the cost of energy can be made.

To consider a site for the application of WECS, the average wind speed should be at least 12 to 14 mph. In evaluating the cost of energy for this study, it was assumed that a wind resource of 15 mph was available.

The annual cost per kilowatt-hour of a wind energy system can be determined by dividing the cost of the system by the production. Obviously, the cost must include life cycle costs (such as O&M) and the energy production must reflect realistic production rates.

The cost for commercial wind turbines has been decreasing steadily since 1981 when the first large wind turbines were installed. The present cost for an installed wind energy system is approximately $1000/kW. O&M expenses for the wind farms are currently running $0.01/kWh produced. The Electric Power Research Institute (EPRI) reports long-term O&M costs to be between $0.008 and 0.012/kWh for recent machines. The availability of the wind machine to produce power is another factor that must be considered. Wind turbines installed between 1981 and 1984 had availabilities of 20 to 70 percent, however, the availabilities of recent machines have been between 80 and 98 percent, significantly improving overall economics.

Combining all of the above factors and considering a site with an average wind resource of 15 mph and installed cost of $1000.00/kW, the cost of energy from a wind energy system is estimated to be roughly $0.08/kWh.

APPENDIX B:

ORGANIZATIONS CONTACTED

Technology Related

Luz International
Sandia National Laboratory
  Photovoltaics Division
  Solar Thermal Power Division
Department of Energy
Tennessee Valley Authority
Arco Solar
Solarex
Entech, Inc.
Intersol, Inc.
American Wind Energy Association
Solar Energy Industry Association

Financing Related

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US Military Academy 10996
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